POWER QUALITY AND REACTIVE POWER COMPENSATION STUDY

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This thesis is submitted as partial fulfillment of the requirements for the award of the degree of Bachelor of Electrical Engineering (Power System)

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NOVEMBER, 2010

"I hereby acknowledge that the scope and quality of this thesis is qualified for the award of the Bachelor Degree of Electrical Engineering (Power System)"

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References of information from other sources are quoted accordingly; otherwise the information presented in this report is solely work of the author."

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ACKNOWLEDGEMENTS

Thanks to Allah for giving me this opportunity, the strength and the patience to complete my project finally, after all the challenges and difficulties.

First and foremost, I would like to express my greatest gratitude to my supervisor Mr. Omar Aliman, who have guide and helped me a lot throughout this final year project. This appreciation is also dedicated to all the FKEE staffs, those who are really generous and helpful.

I also would like to thank to my parents, for supporting me mentally and physically not just during finishing this tasks but also during my whole studies.

Finally, I would like to take this opportunity to thank all my friends who have given their support and help.

Hopefully, this final year project will not be the end of my journey in seeking for more knowledge to understand the meaning of life.

ABSTRACT

Power quality is an issue that is becoming increasingly important to electricity consumers at all levels of usage. There are many major cause effected on this quality of power. In this research, power quality and reactive power compensation in electric radial distribution networks will be analyzed using industrial data network and modeled by using DigSILENT *PowerFactory* software as for simulation. This thesis presents an approximate technique of capacitor placement for loss minimization and power quality as well. In order to analyze for this system it suppose to be concern on the sizing and placement of the capacitors. So then, the power loss is minimized and annual savings are maximized.

ABSTRAK

Kualiti tenaga elektrik merupakan isu yang menjadi semakin penting untuk penguna elektrik di semua peringkat pengguna. Terdapat banyak penyebab utama yang menpengaruhi kepada kualiti tenaga elektrik ini. Dalam kajian ini, kualiti tenaga elektrik dan pampasan daya reaktif dalam rangkaian pembahagian tenaga elektrik akan dianalisis menggunakan rangkaian industri data dan dimodelkan dengan menggunakan perisian DigSILENT *PowerFactory*. Dalam kajian ini juga turut menyediakan teknik anggaran penempatan kapasitor untuk meminimumkan kerugian dan kualiti tenaga elektrik. Dalam proses untuk menganalisis sistem ini mengambil kira pada saiz dan penempatan kapasitor. Jadi, kuasa yang hilang dapat di minimalkan dan penjimatan tiap tahun dimaksimalkan.

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LIST OF ABBREVIATION

KWh	-	Kilo Watt Hour
KW	-	Kilo-Watts
kVA	-	Kilo-Volts Amperes
AC	-	Alternating Current
P	-	Active Power
Q	-	Reactive Power
TNB	-	Tenaga Nasional Berhad

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

The production, transmission and distribution of energy involve important costs such as fixed costs and operating costs. Based on the two types of costs, utility companies have established rate structures that attempt to be as equitable as possible for their customer. The rates are based upon the amount of energy consumed (kWh) and the power factor of the load.

In electrical power consuming, the utility will record energy consumed for billing purpose. If the consumer uses electrical power inefficiently for example used load such as motor, air conditioner and others load which is drawn more current, the power utilities have to supply extra current to make up for the loss caused by poor power factor.

Power factor would be unity, but we have seen in real world, power factor is reducing by highly inductive load to 0.7 or less. This induction is caused by equipment such as lightly loaded electric motors, fluorescent lighting ballasts and welding sets, etc. In Malaysia, the commercial & industrial customers with low power factor below by 0.85 will be charged penalties. Capacitor bank is one of the technique uses for reactive power compensation in the system.

Voltage and Reactive power compensation is an important issue in electric power systems, involving operational , economical and quality of service aspects consumer loads (residential, industrial, service sector, etc.) impose active and reactive power demand, depending on their characteristics. Active power is converted into “useful” energy, such as light or heat. Reactive power must be compensated to guarantee an efficient delivery of active power to loads, thus releasing system capacity, reducing system losses, and improving system power factor and bus voltage profile. The achievement of these aims based on the sizing and allocation of shunt capacitors (sources of reactive power) [2].

Reactive power compensation and voltage regulation are two effective measures to improve the voltage quality. Many works has been done aiming at the optimal compensation on distribution and transmission network. Optimal reactive power compensation (ORPC) models and algorithm research in distribution networks have made numerous progress based on mathematical programming or physical characteristic analysis, Intelligent Search and Heuristic Algorithm [3].

In general, the problem of optimal reactive power planning (ORPP) can be defined as to determine the amount and location of shunt reactive power compensation while keeping an adequate voltage profile.

Quiet sometime ago, evolutionary programming’s (EAs) have been used for optimization; in particular both the genetic algorithm and evolutionary programming have been used in ORPP problem. The EA is a powerful optimization technique analogous to the natural selection process in genetics. Theoretically, this technique converge to the global optimum solution with probability one. Evolutionary algorithm is an inherently parallel process. Recent advances in distributed processing architectures could result in dramatically reduced execution times, and it is now possible to do a large amount of computation in order to obtain the global instead of a local optimal solution [4].

In this study described how to design the capacitor bank in medium voltage system. There have several processes in order to design the capacitor bank, this process involved of determining capacitor size, location and connection type of Wye or Delta. To get the accurate result in capacitor bank design, the optimization capacitor placement should be considered.

In this paper approximate technique will be used in order to analyze the sizing and allocation capacitor bank.

1.2 Project Objectives

The objectives of this project are to:

1. To study a basic design of MV capacitor bank
2. To analyze approximate technique of allocation capacitor bank

1.3 Problems statement

The capacitor placement problem considered in this research is to determine the effect of low power factor, increasing losses in the medium voltage system and thus to avoid power factor penalty.

Power factor is measured of how efficiently or inefficiently that electrical power is used by a customer. It is the ratio between kW (Kilo-Watts) and kVA (Kilo-Volts Amperes) drawn by an electrical load where the kW is the actual (true) load power and the kVA is the apparent load power.

In the effect of low power factor, it has two costly disadvantages for the power user. It can increased the cost incurred by the power company because more current must be transmitted than is actually used perform useful work. This increased cost is passed on to the industrial customer by means of power factor adjustments to rate schedules (Losses, Power Factor Penalty & Loading).

Further, It can reduces the load handling capability of the industrial plants electrical transmission system which that the industrial power user must spend more on transmission lines and transformers to get a given amount of useful power through their plant (Losses and Loading)

1.4 Project scopes

This research will focus on sizing and placement of capacitor bank in distribution network. The research elements would be study on basic design of MV capacitor bank and analyzing an approximate technique to get optimal power factor and also to reduce losses.

The studies for basic design is not involved how to developing the capacitor bank from initial material but only focus to get sizing and placement of the capacitor bank in the distribution system, using two approaches which are doing in practice and also using by simulation. However, dynamic and protection study is not covered in this research study.

Besides, the power quality scope only covers for power factor stability and also for active and reactive power losses. Thus, the studies about the harmonics, sag, swell not cover in these cases of study.

The limitation of getting the real data from utilities for the base case systems have decided to utilise the 43 bus data from industrial network as the test system. The verification will be done by directly applying of approximate techniques and this may not involve in developing those techniques.

Since this research is dealing with real medium voltage system, therefore no testing and live measurement will be done due to safety cautions.

Therefore, the test system will only be simulated by using commercial power system software and depend on its limitation features.

1.5 Thesis outline

This thesis contains of five chapters including Chapter one: Introduction, Chapter two: Literature reviews, Chapter three: Methodology, Chapter four: Result and discussion, Chapter five: Conclusion and Recommendation. Each chapter will contribute to explain different focus and discussion relating with the corresponding chapters heading.

Chapter one is contain introduction which is present about the overviews of the project that is constructed. It consists of project background, objective, problem statement, project scope.

Chapter two is containing literature review which is discussed about the some reference or citation relate to this project title.

Chapter three will discuss about the methodology in this project. This part of methodology is divided by two parts, the first part describes how normally practice does in order to design of capacitor bank and the second one is approximate method which is used in this project.

Chapter four included result and discussion

Chapter five contain conclusion and recommendations for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Reactive power is a subject of great concern for the operation of alternating current (AC) power systems [5]. It has always been a challenge to obtain the balance between a minimum amount of reactive power flow (to maximize capacity for active power flow) and a sufficient amount of reactive power flow to maintain a proper system voltage profile.

Even though reactive power is not widely understood outside of the power engineering community, it remains one of the most important aspects of AC power system operation. Those involved with maintaining and operating power systems must constantly be concerned with the balance between reactive power supply and demand as much as with active power supply and demand. The reliable and economic use of electric power depends on an availability of sources for leading and lagging reactive power that can be appropriately dispatched to the system.

2.2 Reactive Power Compensation

The earliest distribution systems did not use any form of reactive compensation. Any reactive requirements by the components of the system or by the loads served were supplied by the synchronous generator. This led to very inefficient utilization of the system so utility companies developed rate structures that penalized loads of low power factor.

The first uses of shunt capacitors on power systems was in the 1920s, at large industrial plants where reductions in electric charges justified providing local reactive power compensation. Before capacitors, synchronous motors were (and continue to be) employed in industrial plants on processes requiring large amounts of constant mechanical power.

The synchronous motors could be controlled to provide some amount of reactive supply, often enough to compensate for the reactive consumption of induction machines. Synchronous condensers were used, beginning in the 1930s, on transmission and sub-transmission systems to provide a variable source of reactive power.

In the 1930s, the advantages of series capacitors became apparent and began to find applications in distribution systems and industrial installation [6]. Figure 2.1 shows the Photograph of Synchronous Condenser from Hyundai Ideal Electric Company.

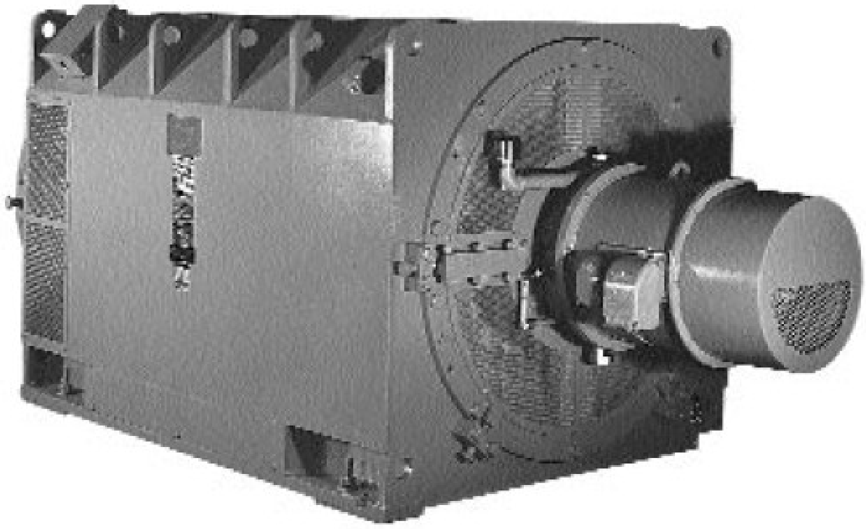


Figure 2.1: Photograph of Synchronous Condenser from Hyundai Ideal Electric Company

2.3 Installation of Capacitor Bank

In electrical power system, capacitors are commonly used to provide reactive power compensation in order to reduce power losses, regulate bus voltage and improve the power factor. The capacitor's size and allocation should be properly considered, if else they can amplify harmonics currents and voltages due to possible resonance at once or several harmonic frequencies. This condition could lead to potentially dangerous magnitudes of harmonic signals, additional stress on equipment insulation, increased capacitor failure and interference with communication system [5].

2.4 Capacitor Bank Placement

The general problem for capacitor placement is to determine the optimal number, location, sizes and switching times for capacitors to be installed on a distribution feeder to maximize cost savings subjected to operating constraints.

The installed sizes for fixed capacitor banks located on distribution lines are based on matching reactive load to available bank sizes as closely as possible. For capacitor banks installed at substations, the size is chosen to maintain suitable power factor at peak loads, compensate for reactive losses in substation transformers, and release substation capacity. See Figure 2.2 for a photograph of an automatically switched, line-mounted capacitor bank and its components.

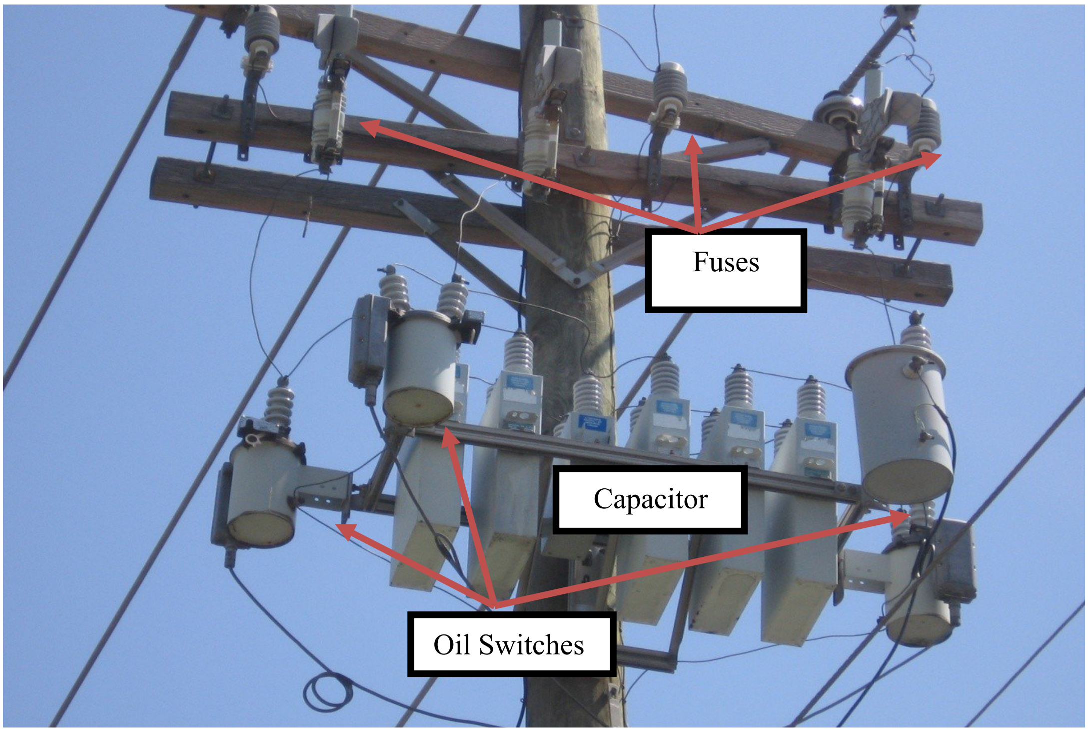
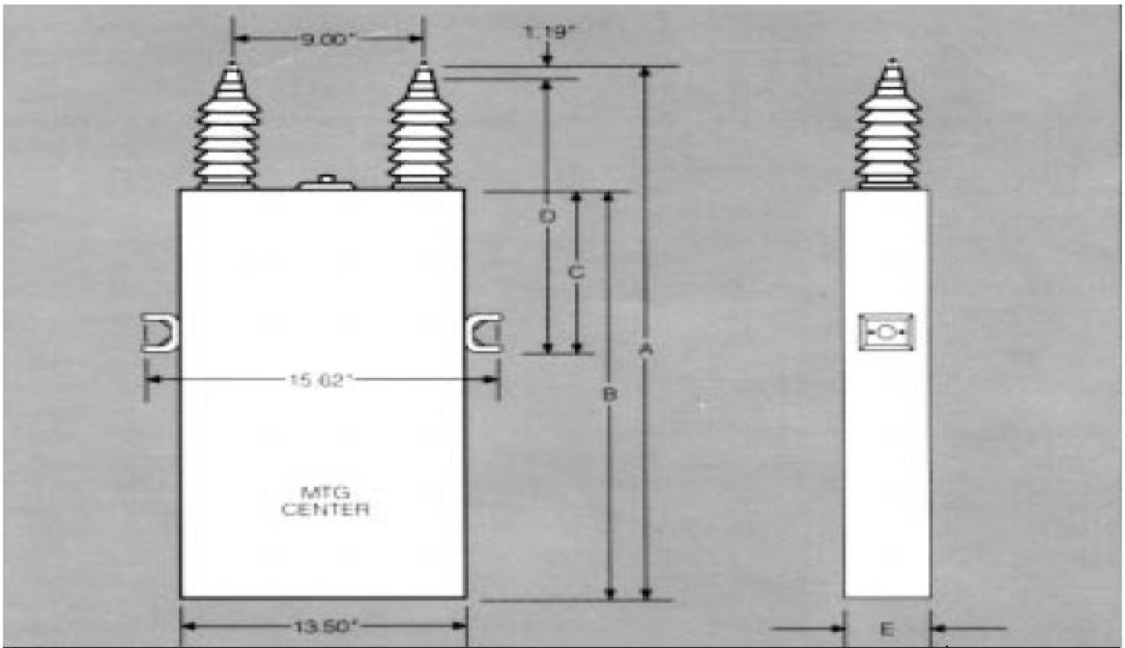


Figure 2.2: Line Mounted Capacitor Bank

Referring to table 2.1, it's showed the dimension and weights of capacitors. This example is taken from Cooper Power System Brochure. Based on this table, noticed that the difference rating of Kvar has their own dimension and weights for capacitors.

Table 2.1: Example of Standard Dimension and Weights of capacitor bank



Ratings			Dimensions					Approx. Net Bushing Capacitor* (lb)
Kvar	Voltage (volts)	BIL (kV)	A	B	C	D	E	
50	2400-4800	75	14.25	6.00	5.88	12.94	4.25	30
	6640-14400	95	14.25	6.00	5.88	12.94	4.25	30
	6640-14400	150	17.87	6.00	5.88	16.56	4.25	34
100	2400-4800	75	18.75	10.50	9.88	12.94	4.25	44
	6640-14400	95	18.75	10.50	9.88	12.94	4.25	44
	6640-24940	150	22.37	10.50	9.88	16.56	4.25	48
150	2400-4800	75	22.50	14.25	9.88	16.94	4.50	58
	6640-14400	95	22.50	14.25	9.88	16.94	4.50	58
	6640-24940	150	26.12	14.25	9.88	20.56	4.50	62
200	2400-4800	75	23.25	15.00	9.88	16.94	5.25	66
	6640-14400	95	23.25	15.00	9.88	16.94	5.25	66
	6640-24940	150	26.87	15.00	9.88	20.56	5.25	70
300	6640-14400	95	31.75	23.50	9.88	16.94	4.50	89
	6640-24940	150	35.38	23.50	9.88	20.56	4.50	93
400	6640-14400	95	31.75	23.50	9.88	16.94	5.75	105
	6640-24940	150	35.38	23.50	9.88	20.56	5.75	109

The allocation of capacitor banks corresponds to one of the most important problems related to the planning of electrical distribution networks. This problem consists of determining, with the smallest possible cost, the